WE CLAIM:

1. In a seismic classification system, a method of generating a classified
result which can be recorded or displayed on a workstation display,
comprising the steps of:

(a) receiving at least a first attribute data set where the attribute data set
includes a plurality of points and a plurality of attribute data
corresponding, respectively, to the plurality of points,

(b) generating a first cross plot in attribute space in response to the
attribute data on the first attribute data set, and

(c) generating the classified result in response to the plurality of points
on the first attribute data set and the first cross plot in attribute space.

2. The method of claim 1, wherein the receiving step (a) for receiving at
least a first attribute data set comprises the steps of:

(a1) receiving a plurality of measurable quantities associated,
respectively, with a plurality of points in a subsurface, the first attribute
data set corresponding to the subsurface, and

(a2) generating the plurality of attribute data "(a, b)" associated,
respectively, with the plurality of points on the first attribute data set.

3. The method of claim 1, wherein the generating step (b) for generating
the first cross plot in attribute space in response to the attribute data on
the first attribute data set comprises the steps of:

(b1) selecting a subset of the attribute data on the first attribute data set
to represent a first set of inspection data,

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(b2) generating a second cross plot in attribute space from the first set of inspection data, the second cross plot having a distribution/separation of clusters, and

5   (b3) evaluating the distribution/separation of the clusters on the second cross plot.

4. The method of claim 3, wherein the generating step (b) for generating the first cross plot in attribute space in response to the attribute data on
10   the first attribute data set further comprises the steps of:

(b4) selecting a subset of points among a set of clusters on the first cross plot in attribute space to represent a second set of inspection data,

15   (b5) generating a second attribute data set from the second set of inspection data, the second attribute data set having a distribution of points, and

(b6) evaluating the distribution of the points on the second attribute data
20   set.

5. The method of claim 4, wherein the generating step (b) for generating the first cross plot in attribute space in response to the attribute data on the first attribute data set further comprises the steps of:
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(b7) selecting some of the attribute data on the first attribute data set to represent training data,

(b8) selecting other attribute data on the first attribute data set to
30   represent validation data, a class of the training data being approximately the same as a class of the validation data,

(b9) generating a third cross plot in a particular attribute space in response to the training data, and

(b10) generating a fourth cross plot in said particular attribute space in response to the validation data, whereby a cluster in said particular attribute space resultant from said validation data should be located adjacent to another cluster in the same said particular attribute space resultant from said training data when said class of said training data is approximately the same as said class of said validation data.

6. The method of claim 5, wherein the generating step (b) for generating the first cross plot in attribute space in response to the attribute data on the first attribute data set further comprises the steps of:

(b11) generating said cross plot in attribute space having at least two clusters of points in response to the attribute data on the first attribute data set when:

the distribution/separation of the clusters on the second cross plot evaluated during the step (b3) is acceptable,

the distribution of the points on the second attribute data set evaluated during the step (b6) is acceptable, and

said cluster in said particular attribute space resultant from said validation data is located adjacent to said another cluster in the same said particular attribute space resultant from said training data when said fourth cross plot in said particular attribute space is generated during the step (b10).

7. The method of claim 1, wherein the generating step (c) for generating the classified result in response to the plurality of points on the first attribute data set and the cross plot in attribute space, having said at least two clusters of points, comprises the steps of:

(c1) assigning a first label to a first one of said at least two clusters of points on said cross plot in attribute space, each point in said first one of said at least two clusters of points on said cross plot in attribute space having assigned thereto said first label and corresponding to a first set of locations on said first attribute

5   data set,

(c2) assigning a second label to a second one of said at least two clusters of points on said cross plot in attribute space, each point in said second one of said at least two clusters of points on said cross plot in attribute space having

10   assigned thereto said second label and corresponding to a second set of locations on said first attribute data set,

(c3) labeling each of said first set of locations on said first attribute data set with said first label, and

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(c4) labeling each of said second set of locations on said first attribute data set with said second label.

8. A seismic classification apparatus adapted for producing a classified result

20   from a plurality of attribute data sets, comprising:

first generation means for generating a plurality of values associated, respectively, with a plurality of points distributed over the surface on a subsurface of an earth formation;

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second generation means responsive to the plurality of values for generating a plurality of labels which are associated, respectively, with the plurality of values; and

30   means for associating the plurality of labels with the respective plurality of points on the subsurface of the earth formation thereby generating a class data set plot comprising the plurality of points which are labeled, respectively, with the plurality of labels, the class data set plot representing the classified result.

9. The seismic classification apparatus of claim 8, wherein the second generation means comprises:

5   selecting means for selecting an inspection subset of said plurality of values;

first clustering means responsive to the inspection subset for clustering said inspection subset of said plurality of values in attribute space; and

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second clustering means for clustering all of said plurality of values in the attribute space when the inspection subset of the plurality of values are clustered acceptably in the attribute space by the first clustering means.

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10. The seismic classification apparatus of claim 9, wherein the selecting means selects the inspection subset of the plurality of values and a training subset of the plurality of values and a validation subset of the plurality of values, and wherein the first clustering means comprises:

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inspection subset clustering means responsive to the inspection subset for clustering the inspection subset of the plurality of values in attribute space;

25   training subset clustering means responsive to the training subset for clustering the training subset of said plurality of values in attribute space; and

validation subset clustering means responsive to the validation subset
30   for clustering the validation subset of the plurality of values in attribute space,

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the second clustering means clustering all of said plurality of values in the attribute space and producing a plurality of clusters of values in the attribute space when the inspection subset of the plurality of values are clustered acceptably in the attribute space by the inspection subset

5   clustering means and when the training subset of the plurality of values are clustered acceptably in the attribute space by the training subset clustering means and when the validation subset of the plurality of values are clustered acceptably in the attribute space by the validation subset clustering means.

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11.   The seismic classification apparatus of claim 10, wherein said second clustering means assigns a plurality of labels, respectively, to said plurality of clusters produced in the attribute space, a separate and distinct label being assigned to each of the clusters in said attribute

15   space.

12.   The seismic classification apparatus of claim 11, wherein said means for associating the plurality of labels, respectively, with the plurality of points on the subsurface of the earth formation further

20   comprises:

data set generation means responsive to the assignment of the plurality of labels, respectively, to the plurality of clusters in the attribute space by the second clustering means for generating a class data set plot

25   representing the classified result, the class data set plot representing an attribute data set plot of the plurality of points distributed over the surface on the subsurface of the earth formation having the plurality of labels associated, respectively, with that plurality of points on the surface of that subsurface.

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13.   A program storage device readable by a machine, tangibly embodying a program of instructions executable by the machine, to perform method steps for

generating a classified result that can be recorded or displayed on a workstation display, said method steps comprising:

(a) receiving at least a first attribute data set where the attribute data set

5   includes a plurality of points and a plurality of attribute data corresponding, respectively, to the plurality of points,

(b) generating a first cross plot in attribute space in response to the attribute data on the first attribute data set, and

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(c) generating the classified result in response to the plurality of points on the first attribute data set and the cross plot in attribute space.

14. The program storage device of claim 13, wherein said receiving

15   step (a) of said method steps for receiving at least a first attribute data set further comprises the steps of:

(a1) receiving a plurality of measurable quantities associated, respectively, with a plurality of points in a subsurface, the first attribute

20   data set corresponding to the subsurface, and

(a2) generating the plurality of attribute data "(a, b)" associated, respectively, with the plurality of points on the first attribute data set.

25   15. The program storage device of claim 13, wherein the generating step (b) of said method steps for generating the first cross plot in attribute space in response to the attribute data on the first attribute data set comprises the steps of:

30   (b1) selecting a subset of the attribute data on the first attribute data set to represent a first set of inspection data,

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(b2) generating a second cross plot in attribute space from the first set of inspection data, the second cross plot having a distribution/separation of clusters, and

5 (b3) evaluating the distribution/separation of the clusters on the second cross plot.

16. The program storage device of claim 15, wherein the generating step (b) of said method steps for generating the first cross plot in attribute
10 space in response to the attribute data on the first attribute data set further comprises the steps of:

(b4) selecting a subset of points among a set of clusters on the first cross plot in attribute space to represent a second set of inspection data,
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(b5) generating a second attribute data set from the second set of inspection data, the second attribute data set having a distribution of points, and

20 (b6) evaluating the distribution of the points on the second attribute data set.

17. The program storage device of claim 16, wherein the generating step (b) of said method steps for generating the first cross plot in attribute
25 space in response to the attribute data on the first attribute data set further comprises the steps of:

(b7) selecting some of the attribute data on the first attribute data set to represent training data,
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(b8) selecting other attribute data on the first attribute data set to represent validation data, a class of the training data being approximately the same as a class of the validation data,

(b9) generating a third cross plot in a particular attribute space in response to the training data, and

5   (b10) generating a fourth cross plot in said particular attribute space in response to the validation data, whereby a cluster in said particular attribute space resultant from said validation data should be located adjacent to another cluster in the same said particular attribute space resultant from said training data when said class of said training data is

10   approximately the same as said class of said validation data.

18.   The program storage device of claim 17, wherein the generating step (b) of said method steps for generating the first cross plot in attribute space in response to the attribute data on the first attribute data set comprises the steps

15   of:

(b11) generating said cross plot in attribute space having at least two clusters of points in response to the attribute data on the first attribute data set when:

20   the distribution/separation of the clusters on the second cross plot evaluated during the step (b3) is acceptable,

        the distribution of the points on the second attribute data set evaluated during the step (b6) is acceptable, and

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        said cluster in said particular attribute space resultant from said validation data is located adjacent to said another cluster in the same said particular attribute space resultant from said training data when said fourth cross plot in said particular attribute space is generated during the step (b10).

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19.   The program storage device of claim 13, wherein the generating step (c) of said method steps for generating the classified result in response to the

plurality of points on the first attribute data set and the cross plot in attribute space, having said at least two clusters of points, comprises the steps of:

(c1) assigning a first label to a first one of said at least two clusters of points on said cross plot in attribute space, each point in said first one of said at least two clusters of points on said cross plot in attribute space having assigned thereto said first label and corresponding to a first set of locations on said first attribute data set,

(c2) assigning a second label to a second one of said at least two clusters of points on said cross plot in attribute space, each point in said second one of said at least two clusters of points on said cross plot in attribute space having assigned thereto said second label and corresponding to a second set of locations on said first attribute data set,

(c3) labeling each of said first set of locations on said first attribute data set with said first label, and

(c4) labeling each of said second set of locations on said first attribute data set with said second label.

20. A seismic classification system adapted for producing a classified result adapted from a plurality of attribute data, comprising:

first means for receiving said plurality of attribute data, said plurality of attribute data corresponding to a plurality of points on a first attribute data set;

second means for generating a first cross plot in attribute space in response to the plurality of attribute data on the first attribute data set; and

third means for generating a classified result in response to the plurality of points on the first attribute data set and the first cross plot in attribute space.

21. The seismic classification system of claim 20, further comprising a display adapted for displaying said classified result.

22. The seismic classification system of claim 20, wherein said first means for
5   receiving said plurality of attribute data comprises:

measurable quantity receiving means for receiving measurable quantities associated, respectively, with a plurality of points in a subsurface, the first attribute data set corresponding to said horizon; and
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means responsive to the receipt of said measurable quantities associated, respectively, with the plurality of points in the subsurface by said measurable quantity receiving means for generating the plurality of attribute data "(a, b)" associated, respectively, with the plurality of points on the first attribute data
15   set.

23. The seismic classification system of claim 20, wherein said second means for generating said first cross plot in attribute space in response to the plurality of attribute data on the first attribute data set comprises:
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means for selecting a subset of the attribute data on the first attribute data set to represent a first set of inspection data,

means for generating a second cross plot in attribute space from the first set
25   of inspection data, the second cross plot having a distribution/separation of clusters, and

means for evaluating the distribution/separation of the clusters on the second cross plot.
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24. The seismic classification system of claim 23, wherein said second means for generating said first cross plot in attribute space in response to the plurality of attribute data on the first attribute data set further comprises:

means for selecting a subset of points among a set of clusters on the first cross plot in attribute space to represent a second set of inspection data,

5 means for generating a second attribute data set from the second set of inspection data, the second attribute data set having a distribution of points, and

means for evaluating the distribution of the points on the second

10 attribute data set.

25. The seismic classification system of claim 24, wherein said second means for generating said first cross plot in attribute space in response to the plurality of attribute data on the first attribute data set further comprises:

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means for selecting some of the attribute data on the first attribute data set to represent training data,

means for selecting other attribute data on the first attribute data set to

20 represent validation data, a class of the training data being approximately the same as a class of the validation data,

means for generating a third cross plot in a particular attribute space in response to the training data, and

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means for generating a fourth cross plot in said particular attribute space in response to the validation data, whereby a cluster in said particular attribute space resultant from said validation data should be located adjacent to another cluster in the same said particular attribute

30 space resultant from said training data when said class of said training data is approximately the same as said class of said validation data.

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26. The seismic classification system of claim 25, wherein said second means for generating a first cross plot in attribute space in response to the plurality of attribute data on the first attribute data set further comprises:

5   means for generating said first cross plot in attribute space having at least two clusters of points in response to the attribute data on the first attribute data set when:

the distribution/separation of the clusters on the second cross plot is
10   acceptable,

the distribution of the points on the second attribute data set is acceptable, or

15   said cluster in said particular attribute space resultant from said validation data is located adjacent to said another cluster in the same said particular attribute space resultant from said training data when said fourth cross plot in said particular attribute space is generated.

20   27. The seismic classification system of claim 20 wherein said first cross plot in attribute space has at least two clusters of points, and wherein said third means for generating a classified result in response to the plurality of points on the first attribute data set and the first cross plot in attribute space comprises:

25   means assigning a first label to a first one of said at least two clusters of points on said first cross plot in attribute space, each point in said first one of said at least two clusters of points on said first cross plot in attribute space having assigned thereto said first label and corresponding to a first set of locations on said first attribute data set,

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means for assigning a second label to a second one of said at least two clusters of points on said first cross plot in attribute space, each point in said second one of said at least two clusters of points on said first cross plot in attribute

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space having assigned thereto said second label and corresponding to a second set of locations on said first attribute data set,

means for labeling each of said first set of locations on said first attribute data
5   set with said first label, and

means for labeling each of said second set of locations on said first attribute data set with said second label.

10   28. The seismic classification system of claim 26 wherein said first cross plot in attribute space has at least two clusters of points, and wherein said third means for generating a classified result in response to the plurality of points on the first attribute data set and the first cross plot in attribute space comprises:

15   means assigning a first label to a first one of said at least two clusters of points on said first cross plot in attribute space, each point in said first one of said at least two clusters of points on said first cross plot in attribute space having assigned thereto said first label and corresponding to a first set of locations on said first attribute data set,

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means for assigning a second label to a second one of said at least two clusters of points on said first cross plot in attribute space, each point in said second one of said at least two clusters of points on said first cross plot in attribute space having assigned thereto said second label and corresponding to a second
25   set of locations on said first attribute data set,

means for labeling each of said first set of locations on said first attribute data set with said first label, and

30   means for labeling each of said second set of locations on said first attribute data set with said second label.

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